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Modeling the combustion process of a powerful diesel engine

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Abstract

The authors develop models of the combustion process and a program for calculating the operating cycle of a powerful diesel engine with the set law of mixture formation. They also calculate how the temperature of a fresh charge after a charge air cooler impacts the operating cycle indicators of such an engine. Based on the results of the calculation, herein are constructed charts of in-cylinder pressure and heat release laws that accord with known experimental data.

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Keywords: powerful diesel, calculations, operating cycle, indicator parameters, the maximum combustion pressure, modeling, combustion process, molecules of fuel, the law of mixture formation, the temperature of the fresh charge, charge air cooler;

1. The peculiarities of combustion process in the diesel engine and models for its description

It is admitted that at fuel combustion the reaction rate initially increases, but as the process unfolded under certain conditions, it decreases.

By the simulation, theoretical and experimental research of the fuel combustion in the diesel engine it is determined that in the compression volume the two areas, the higher temperature area and the lower temperature area, are distinguished [1]. And in some areas the temperature reaches 3000ºK (with the average temperature 1700-1800ºK) and changes insignificantly within 50-60 degrees of the crankshaft position [2]. It indicates that when the temperature reaches 3000ºK, the processes of the carbon dioxide dissociation limit the further progress of the combustion, and in the expansion process the carbon monoxide afterburning sustain the higher temperature until it is

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fully oxidized.

The known models, which are used for mathematical formulation of the fuel combustion process in the internal-combustion engine, either consider this characteristics incompletely, or consider them in the implicit form. Therefore, the development of the combustion theory and making new models for the description of the real in-cylinder processes still remain urgent.

All the known combustion process models may be divided into three principal groups:

- models in which the heat generation process is described by the preset function of time or the crankshaft position;
- models which describe in detail the kinetics of the combustion process;
- models which are based on the application of the general kinetic law (Arrhenius equation).

Simple and useful combustion process models among which I.I. Wiebe's model became widespread refer to the first group [3]. The real variation of the parameters of the actuating medium (pressure, temperature and concentration of the reactants) in the combustion process are not considered in the models of this group. The combustion products dissociation heat losses are taken into consideration in the implicit form, as a rule, with the other heat losses which are expressed in terms of the heat utilization factor or the combustion efficiency factor. And the value of the dissociation heat losses is considered proportional to the part of the burnt fuel, and in the expansion process this heat doesn't return to the actuating medium.

The second group includes models that treat the fuel oxidation process by atmospheric oxygen as the combination of chemical reactions with the intermediate products generation [4,5]. For each similar reaction there are constants of reaction rate, activation energy and reagents concentration. It is too difficult to realize the models of this group in engineering computations as it demands great computational power.

The third group includes models that describe the combustion process in general and consider such important physical parameters as the temperature of the actuating medium and the fuel and oxygen concentration [1]. Meanwhile, in the models of this group there is no direct accounting of inert components (nitrogen, combustion products, etc.) that, as it's well-known, inhibits the combustion process. The key parameter of the process in these models is the combustion rate depending of the temperature and the concentration of the mixture active components. The relative quantity of the reactive fuel is not frequently used.

The parameters that characterize the time factor of the combustion process are applied to determine integrated timing values: an ignition delay period estimation and combustion duration with the constant reaction rate or isothermal reaction [6]. However, to model a variable reaction rate with the constantly decreasing fuel and oxygen molecule concentration and considerable temperature rise, it is necessary to control the time dynamics of the combustion process variation. Therefore, it became necessary to introduce the fuel oxidation reaction time factor which allows to control the state of the actuating medium in the engine cylinder in any time (on any process stage).

The Internal-Combustion Engine department of South Ural State University developed a new single-area model of the combustion process based on kinetic equations which more accurately considers the features of in-chamber processes of internal-combustion engines.

2. New models for computation of the fuel combustion process in the diesel engine

2.1. The Combustion Process Model

The Combustion Process Model is based on the following points:

- The whole combustion process is considered as a combination of successive oxidation reactions of active fuel molecules groups to carbon dioxide and water. These reactions progress according to Arrhenius equation and possess the energy that is larger than the conditional activation energy by the present temperature.
- The quantity of reacting active fuel molecules in the group depends on the total quantity of fuel molecules, the current mixture temperature and the conditional activation energy that changes according to the burnt fuel ratio.
- The conditional oxidation duration of active molecules in this group is considered dependent not only on the total quantity of fuel molecules but also such important for the combustion process parameters as the volume of the